SCIENCE AND ENGINEERING FOR WHOLE OF LIFE: INTEGRATING EDUCATION, RESEARCH AND PUBLIC ENGAGEMENT IN A COLLABORATIVE ENVIRONMENT

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Abstract

Policy makers increasingly recognise that an educated workforce with a high proportion of Science, Technology, Engineering and Mathematics (STEM) graduates is a pre-requisite to a knowledge-based, innovative economy. Over the past ten years, the proportion of first university degrees awarded in Australia in STEM fields is below the global average and continues to decrease from 22.2% in 2002 to 18.8% in 2010 [1]. These trends are mirrored by declines between 20% and 30% in the proportions of high school students enrolled in science or maths. These trends are not unique to Australia but their impact is of concern throughout the policy-making community.

To redress these demographic trends, QUT embarked upon a long-term investment strategy to integrate education and research into the physical and virtual infrastructure of the campus, recognising that expectations of students change as rapidly as technology and learning practices change. To implement this strategy, physical infrastructure refurbishment/re-building is accompanied by upgraded technologies not only for learning but also for research. QUT's vision for its city-based campuses is to create vibrant and attractive places to learn and research and to link strongly to the wider surrounding community.

Over a five year period, physical infrastructure at the Gardens Point campus was substantially reconfigured in two key stages: (a) a >$50m refurbishment of heritage-listed buildings to encompass public, retail and social spaces, learning and teaching "test beds" and research laboratories and (b) destruction of five buildings to be replaced by a $230m, >40,000m^2 Science and Engineering Centre designed to accommodate retail, recreation, services, education and research in an integrated, coordinated precinct.

This landmark project is characterised by (i) self-evident, collaborative spaces for learning, research and social engagement, (ii) sustainable building practices and sustainable ongoing operation and (iii) dynamic and mobile re-configuration of spaces or staffing to meet demand. Innovative spaces allow for transformative, cohort-driven learning and the collaborative use of space to prosecute joint class projects. Research laboratories are aggregated, centralised and "on display" to the public, students and staff.

A major visualisation space – the largest multi-touch, multi-user facility constructed to date – is a centrepiece feature that focuses on demonstrating scientific and engineering principles or science oriented scenes at large scale (e.g. the Great Barrier Reef). Content on this visualisation facility is integrated with the regional school curricula and supports an in-house schools program for student and teacher engagement. Researchers are accommodated in a combined open-plan and office floor-space (80% open plan) to encourage interdisciplinary engagement and cross-fertilisation of skills, ideas and projects. This combination of spaces re-invigorates the on-campus experience, extends educational engagement across all ages and rapidly enhances research collaboration.

Keywords: collaboration, functional integration, science, technology, engineering and maths

1 INTRODUCTION

The Office of the Australian Chief Scientist presents arguments for the proposition that community prosperity depends on a majority of the workforce being conversant and well trained in mathematics, engineering and science (MES) [1]. In comparison to global rankings, Australia's university graduation rate in MES is lower than the international average while the share of Science, Technology, Engineering and Mathematics (STEM) first degrees in an annual cohort has decreased from 22.2% in 2002 to 18.6% in 2010 [1]. These first degree percentages compare with an international average of 26.4% in 2002.

Detailed data on high school participation in MES reveal a steadily decreasing trend in participation across all science and engineering-related disciplines from 1992 to 2010. Between 1992 and 2010, participation rates for year 12 students in biology, physics and chemistry fell by 32%, 31% and 23%, respectively [1]. Furthermore, while many high school students continued to participate in mathematics – the curriculum requires math to be taken in many states – there has been an overwhelming shift to elementary, or basic standard, classes. At the same time, the proportion of higher level, or advanced, mathematics participants has dropped from over 14% to about 10% over a 15 year period [1] while enrolments have increased.

A subsequent position paper benchmarked research performance against international standards and noted that Australian science has an overall citation rate well above the world average and slightly below the European average [2]. About 50% of Australian science has an international connection through co-authorship and, in many disciplines, performs above the European average (approximately 78 out of 192) and well above the world average [2]. These data suggest that Australia's research performance, particularly in the STEM fields, is robust and competitive. Yet the disconnect between high school participation trends in STEM education and the long-term outlook for STEM literacy and future production of highly trained, proficient practitioners in these fields is of concern to many policy makers and educators. These concerns are formulated in a range of policy documents generated by various levels of government including a comprehensive report linking national-scale innovation to science engagement [3]. A critical and salient recommendation from this report is to develop the means to "*strongly articulate the goal of a scientifically engaged Australia and support development of strategic national priorities for communicating science and its benefits* [3]".

A third paper by the Office of the Chief Scientist [4] captures the national concern and presents a strategic plan to address the challenges ahead. In this strategic plan, it is noted that the value of investments in STEM education and research are diminished if there is no appropriate regard for society and its aims and aspirations for science. This plan specifically links investment in STEM education and research to the value of the social sciences and humanities and proposes a renewed social compact that provides STEM proponents a context within which a licence to operate may be put into effect [4]. This strategy, schematically described in Fig. 1 Primary purpose of STEM in our community, captures the essence of the study by Questacon [3] and earlier policy documents. That is, maximum benefit to a community arises from integration of education, research and public engagement in the STEM disciplines.

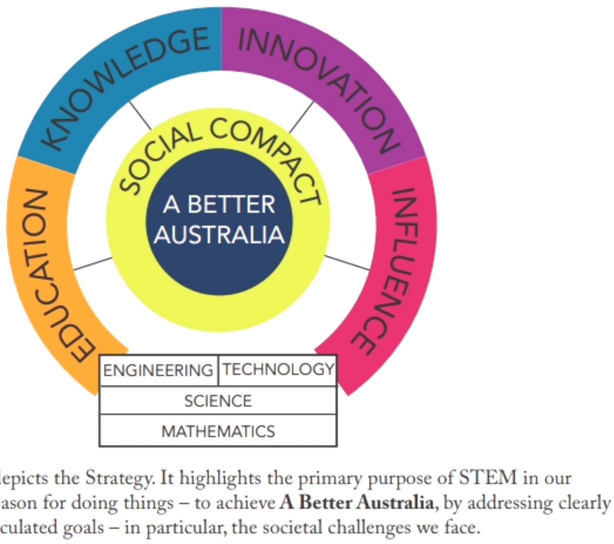

Fig. 1 Primary purpose of STEM in our community (from [4])

Similar calls to arms are occurring in most developed and developing countries as policy-makers understand the implications of a global knowledge economy. Sentiments similar to the Australian reports are expressed in a report to the President of the United States [5]. This report suggests the USA will need to increase its STEM graduates by 34% annually over the next ten years in order to retain its historical pre-eminence in these fields. While these targets are ambitious, they are more so in the context of a rapidly changing technological world, shifting attitudes and expectations of students and the relevance of physical environments for learning and teaching. The challenges faced by the Higher Education Sector in Australia are detailed in recent publications [6, 7] which refer to the democratisation of knowledge, contestability of markets, digital technologies and the mobility of students as key drivers to the educational experience and, by inference, the development of STEM practitioners linked to community values.

This paper describes a response to these challenges in the education and research sector focused on the Gardens Point campus through a collaborative funding partnership between the Australian and Queensland Governments, Atlantic Philanthropies and QUT. This work outlines strategies undertaken to deliver not only a vibrant and attractive place to learn and research but also a campus with strong and consistent links into the wider community. Physical infrastructure re-development at the Gardens Point campus is dictated by the local environment and it is distinctly different to that taken at QUT's other major campus at Kelvin Grove [8]. The key focus at Gardens Point is to integrate education, research and community engagement to enhance accessibility and to provide a source of inspiration and excitement about STEM disciplines for current and future generations.

This paper describes the physical infrastructure and operational changes required to effect broad-ranging changes to community engagement for learners of all ages: pre-school, primary and high school students, active academics, interested bystanders and corporate and government professionals. At a time when some Australian institutions are concerned about the role of a physical campus and the impact of technology on infrastructure use, QUT is investing in whole of life educational engagement on its campuses. This re-development of the Gardens Point campus, substantially completed by April 2102, is already delivering real benefits and cultural change.

2 PHYSICAL INFRASTRUCTURE RECONFIGURED

2.1 Campus – community setting

The QUT Gardens Point (GP) Campus is situated on the edge of the Brisbane CBD, 1km from the centre of the business and shopping district and 0.5km across the river via the Goodwill Bridge to the South Bank Parklands, the Queensland Performing Arts Centre, Museums, Galleries and major public event locations. Fig. 2 Campus location, highlights the strategic location of the GP campus with respect to the political, business and entertainment foci of the City of Brisbane. Accordingly, transport infrastructure is well developed and access to the campus suits pedestrians, cyclists, motorists and public transport users (e.g. trains, buses and river ferries).

Fig. 2 Campus location

Prior to major reconfiguration of the GP campus, many buildings were a mix of post-1960s and heritage-listed stock from previous use as a technical college or institute. Government House [9] was the first public building in Queensland and the hub of colonial life in the early days of Brisbane (1850−1900). This building first housed the University of Queensland in 1910 before moving 7km upriver to the suburb of St Lucia in the 1930's. This building, now called "Old Government House" was extensively restored in time for its 150th anniversary in 2010. QUT retains custodial responsibility for this educational and cultural meeting space that also houses a nationally-renowned art gallery dedicated to William Robinson.

2.2 GP campus transformation

In 2009, existing buildings on the south east edge of the campus were in poor condition, of large footprint and, in the main, with only two levels of usable floor space. The amenity of Gardens Point Road presented an undesirable path through the campus and rarely attracted community activity of any type. A schematic of the GP campus, compact at ~12 hectares, is shown in Fig. 3 Gardens Point Campus – key transformations. This figure outlines the major infrastructure changes implemented from 2009 through to 2012 including the "Early Works/Wet Labs Project" and the "Science and Engineering Centre (SEC)". The Early Works/Wet Labs project included re-design and redeployment of learning and teaching areas, social spaces and laboratories for conduct of research. The project to transform the South East edge of the campus and the early enabling projects is the largest undertaken by QUT and represents a combined investment of ~A$300million over this four year period.

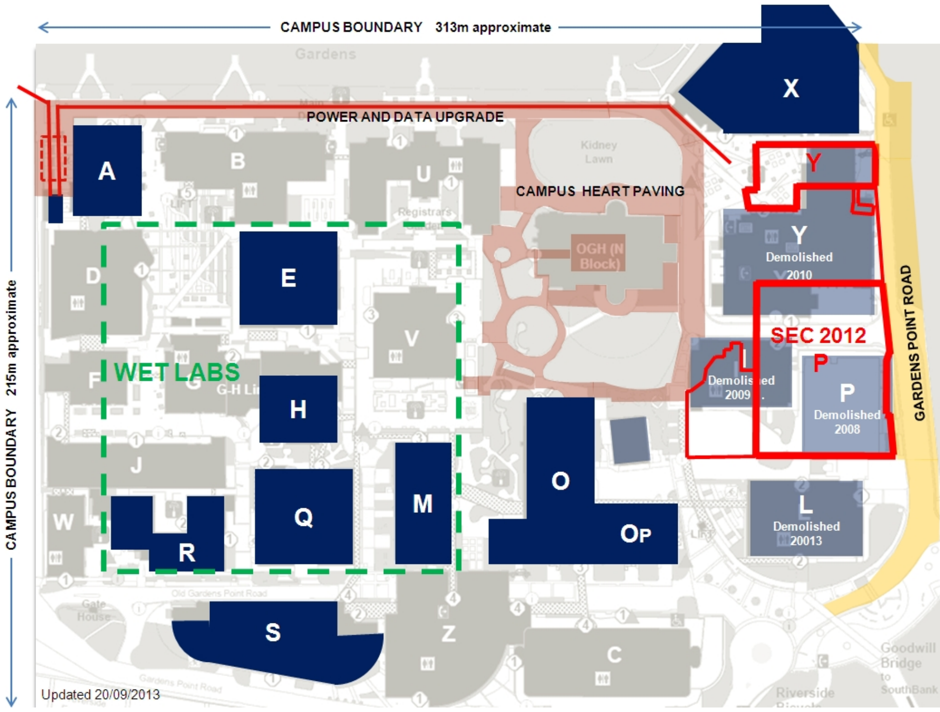

Fig. 3 Gardens Point Campus – key transformations

Transformation of the GP Campus required re-location of academic and professional staff on at least two occasions and resulted in demolition of five buildings, refurbishment of nine other buildings (many of which are heritage listed), redesign and upgrading of landscaping and pedestrian access and major upgrades of utility services. The demolished buildings are replaced by a modern, engaging and architecturally sympathetic building that integrates education, research and community engagement.

Design concepts were extensively tested in the Early Works Project through evaluation of student and staff use and practical feedback to user groups during the early design phase of the SEC. These changes to the physical amenity of the GP Campus were accompanied by constructive engagement with staff and students to minimize disruption to ongoing classes as well as to develop strategies to maximize use of the new University fabric. These strategies arose from an evaluation of research practice, pedagogy, curricula, organizational structure and community engagement.

A key planning element is that student expectations change as rapidly as technology and learning practices change. To implement this strategy, physical infrastructure refurbishment/re-building is accompanied by upgraded technologies not only for learning but also for research. QUT's vision for its city-based campuses is to create vibrant and attractive places to learn and research and to link strongly to the wider surrounding community.

2.3 Early Works Transformations

The early and enabling projects in advance of the SEC not only allowed for decanting the buildings on the site and for continuity of business, but also ensured that design, operation and pedagogical approaches were informed by user feedback on viability. A few key components of this Early Works Project are described below. In total, these early works required more than 1,000 person moves over four years (in some cases, staff were moved three times) with minimal disruption to the daily business of the University.

2.3.1 Engineering laboratories and workshops

The Engineering Laboratories (O block in Fig.3) re-development encompassed many new concepts for QUT's science and engineering community. These concepts included: flexibility as an underpinning principle along with modularisation of previously fixed teaching and learning equipment; high utilisation of spaces; dynamic pedagogical approaches incorporating experiential learning environments, co-location of storage, co-location of technical staff, provision of fundamental services to all areas and specialisation of laboratories only where necessary.

A light, open and connected precinct of laboratories, workshops, student collaboration zones and technical staff offices provide a fresh inviting space compared with the previously closed, industrial style technical facilities. Other functions were added to a previously drab engineering environment. For example, an area known as "the garden lounge" is an adjacent social space set aside for any student in the University to engage in activities usually not allowed in a laboratory environment such as eat, drink, relax and socialise. Visual connections created between social and formal learning environments create an engagement between the formal laboratory function and the lounge space in order to share the excitement of an activity.

A commitment to flexible delivery required a revolutionary approach to undergraduate laboratory experiments. The essential change was to place the majority of laboratory experiments on benches/pedestals that can be wheeled by one person from place to place to suit a purpose or to store. A capacity to move laboratory experiments on demand allows spaces to be reconfigured in minutes and to be utilised in ways far beyond that of fixed laboratories. Due to design requirements placed on vendors of educational equipment, these formats and concepts are now the latest product listings by successful suppliers in Australia.

Fig. 4 Open plan laboratory spaces with mobile laboratory experiments

A large open space that was once a cluttered, but dedicated thermodynamics laboratory is now open, inviting and used for a wide range of activities from school visits and student practical classes to career days and motor sport launch functions for undergraduates. Fig.4 shows this revitalized space in use for an undergraduate engineering class; a mobile bench for laboratory experiments is arrowed.

2.3.2 Staff and higher degree research spaces

S Block (see Fig. 3) was refurbished to accommodate staff and higher degree research students displaced as a result of demolition as well as to transform to collaborative learning spaces in open active environments. The work and approach to design is explained by the architects on their web site

[17] and it states: "*New planning solutions opened up the floors, bringing more natural light into the centre, whilst creating a collaborative, contemporary workplace for students and staff*." Many of these floors were converted to combine open plan areas with glass-walled offices and meeting rooms to establish visual and communication links within a previously narrow, corridor-rich building.

The lower level of a significant heritage building in H block was initially used as an industrial engineering workshop in pre-University days. This ground floor level of H Block was converted from an under utilised junk store and unused laboratory to a revitalized, themed workspace for higher degree research (HDR) students.

For this project, design guidelines including assignment of workspace by utilization were developed. The architects document this project on their web site [18] stating: "*The concept behind the adaptive reuse of Queensland University of Technology's H Block design was 'The Secret Garden,' inspired by the location of the block hidden amongst the other buildings. The Secret Garden also reflects the notion of new thought and the powerful mind, a sanctuary for the higher degree research students who study there. The space was designed to optimise multi-functionality and flexibility, including workstations which can be reconfigured by the user, a large studio space for group work, meeting rooms, offices and a kitchenette. Encouraging academic interaction, the space is a place for students to call home away from home*." Fig.5 shows views of this refurbished heritage building.

Fig.5 Refurbished heritage building for use by HDR students

The Early Works project also included the first building demolition (P Block) and the removal of some research laboratories from the Gardens Point campus. These laboratories were predominantly heavy engineering facilities associated with Civil, Structural and Mechanical Engineering. Over a lengthy three year period, the bulk of this capability, along with Power and Process Engineering and Geosciences facilities were re-located to an off-site industrial park and renamed the Banyo Pilot Plant Precinct. Details of these facilities, along with the re-design and development of research laboratories for common, multi-user synthesis or characterization, will be provided in a later publication.

2.4 Science and Engineering Centre

A high-level strategic planning document, endorsed by the University Council and called the "QUT Blueprint" [10] was revised in 2007 to initiate planning for the construction of the new SEC precinct and a series of wide-ranging reforms. These reforms were based on earlier experience in transforming the other major QUT campus at Kelvin Grove via an "Urban Village" concept [8] and encompassed a fundamental rethink of education, research and community engagement in STEM. By late 2012, SEC construction was complete with integrated functionalities for education, research and community engagement as schematically shown in Fig. 6 Cross section for the SEC showing integration of uses/functionality for campus community.

This landmark project for QUT is a hub for innovative learning and teaching, a catalyst for collaborative research, an exciting meeting place and a model for sustainable building practices.

Implementation of the strategic plan and building designs occurred over four years with a consequential re-location of more than 600 persons in a period of two months with minimal disruption to academic programmes.

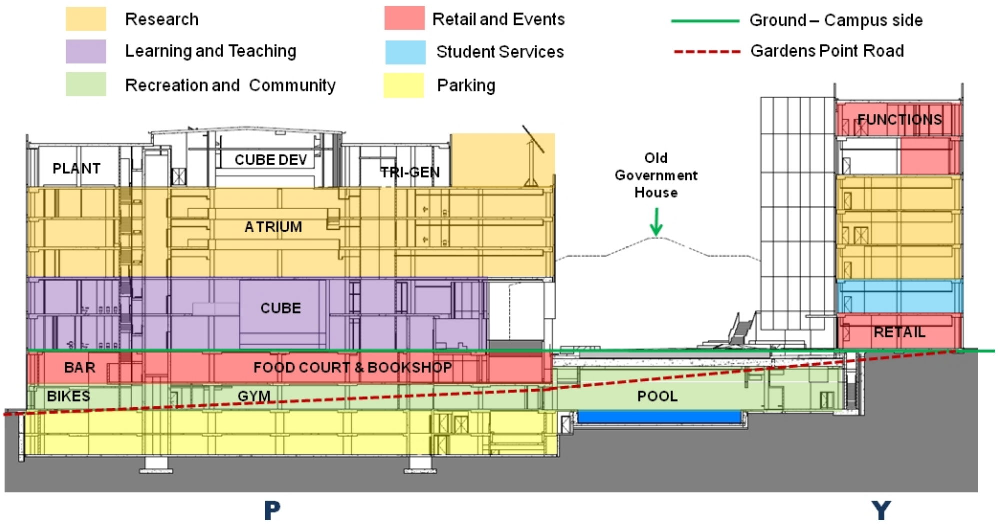

Fig. 6 Cross section of the SEC showing integration of uses/functionality for campus community

2.5 Collaborative spaces

Universities are investing in new learning spaces and development of student community hubs. In particular, libraries have transformed dramatically over recent years, with stacks of books replaced by student group learning and interactive zones. Ease of access to online resources and learning materials have resulted in these spaces – attractively furnished with full digital capability – heavily utilized by the student population. The digital revolution is not only occurring at home but also at university. The Australian Learning and Teaching Council supported project, *Designing Next Generation Places of Learning*, developed a descriptor of the various physical places for learning as shown in Fig. 7 Place for learning - spectrum. The project outcomes have helped Australian institutions to develop and use learning spaces that encourage student engagement and improve learning outcomes [11].

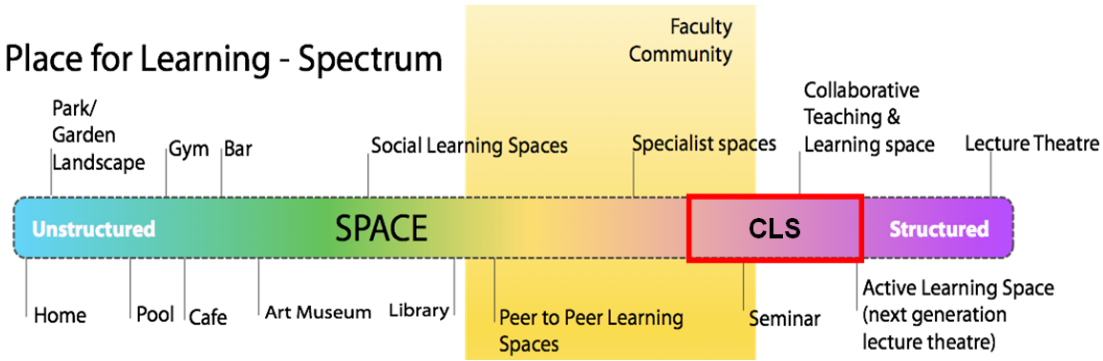

Fig. 7 Place for learning - spectrum

2.5.1 *Collaborative Learning*

New spaces designed to facilitate active and collaborative learning supported by technology are known by many names. These types of spaces include mixtures of furniture, layout and technology that support active and collaborative learning. QUT staff use the term “Collaborative Learning Space” (CLS) to describe these areas that are sometimes known as 21st Century or Next Generation Learning Spaces. Key organisations such as the Joint Information Systems Committee in the United Kingdom produce comprehensive design guidelines that state: *“A learning space should be able to motivate learners and promote learning as an activity, support collaborative as well as formal practice, provide a personalised and inclusive environment, and be flexible in the face of changing needs”* [12] These guidelines also identify CLSs as change agents in their own right [12].

The design of the SEC was preceded by significant trial and testing of smaller learning and group activity areas within other locations at the Gardens Point campus. For example, the library, key lecture halls (S and Z Blocks in Fig. 3) and laboratory spaces were re-designed using concepts that evolved through trial and error at both campuses. This experience led to ready acceptance and strong collaboration by all stakeholders in the implementation of design principles for CLS within the SEC. The complete spectrum of spaces described in Fig. 5 are incorporated in the physical infrastructure of the SEC and, to some extent, even replicate the home environment with installations of eclectic retro furniture adding to the feel of a typical Queensland abode: welcoming and comfortable.

Structured, formal locations for collaborative learning include low tiered lecture theatres that invite speakers and facilitators to move into the midst of learners with table top desks, two to a tier, where group interaction is enabled (through providing space for seated persons to readily turn around to their peers behind). Stitched multiple projection, multiple device inputs, power in desks and mixed mode output along with full wireless coverage and a web camera on speaker(s) and audience provide flexible delivery of visuals and interaction by all participants. All lecture theatres and spaces in the learning and teaching floors feature maximum visual connection via glass walls with drop blinds that can be lowered from the lectern control if required.

Creating immersive experiences that draw on infrastructure, technology and activities necessitates a unique approach to learning delivery design. Rasmussen and Dawes [13] have reported on the application of collaborative learning in SEC for a cohort of 800+ first year engineers in the context of learning and developing professional skills that are representative of engineering practice. Other examples of reporting on new active learning spaces and practice are from Educause and the University of Minnesota such as reported by Brooks [14] and Whiteside and Brooks [15].

Before construction commenced on SEC, a community of practice for new learning environments was established. This commenced in 2009 with a view to ramp up academic skills in the use of collaborative learning spaces and to inform the physical design of those spaces due to come on-line in 2012. An existing room was converted to an experimental pilot space and classes programmed to use the space. The University had three other similar spaces on the Kelvin Grove Campus. At the end of 2013, the combined CLS locations at QUT numbers seventeen. The community of practice has also transformed into a formal training and support section of the university called LATICE (Learning and Teaching in Collaborative Environments). The LATICE project [16] is focused on assisting academics to design, develop and implement new pedagogical approaches that make the most of QUT's innovative learning spaces.

2.5.2 Public Spaces

Public spaces within the SEC are fundamentally designed to educate – particularly about STEM – and to engage all campus participants in collaborative or group social learning as needs arise. Public spaces are also excellent locations for academic, cultural, multi-media or celebratory events. The SEC entry floor includes a massive multi-touch and multi-projection facility called "the Cube" [19] that invites engagement and participation. Community facilities such as a gym, swimming pool, food outlets, bookstore and student lounge are located below the ground floor podium and are accessible by all visitors to the campus.

The public spaces are effective environments for engagement with school students – either formally or informally – using the digital media and components (e.g. interactive Wii stations; touch tables; touch screens; desktops) or the CLS areas embedded within the two public floors. In addition, a separate dedicated CLS is set aside for school students for exclusive use to undertake projects, learn from University academics or develop their own interests.

In the heart of the SEC, the Cube [19] makes a bold statement about community engagement and the connection of schools to the university. This project – conceived, designed and implemented by QUT staff and students in a collaborative engagement across many skill sets and academic disciplines – combines 48 multi-touch screens and very large scale projection to support science and engineering animation and simulation for up to 70,000 visitors per week [20]. The Cube has five interactive zones with content including a "Physics Wall", a "Flood Wall", a "Reef Wall" and other descriptive and instructional material. The Physics Wall, for example, describes the scientists and the basic laws of physics for force, motion, sound, gravity and electromagnetism that they derived. These interactive segments are as instructive for high school students as for their parents and grandparents; another form of collaborative engagement commonly encountered in the SEC.

The QUT STEM High School Engagement program of curriculum linked, practical and innovative workshops and activities provides high school students with engaging and inspirational experiences in STEM. A STEM Teacher in Residence, along with Student Ambassadors and supporting staff deliver cutting edge workshops that integrate building and energy systems data from SEC along with Cube-based activities.

This program aligns with Federal and State Government goals to boost the number of students choosing STEM subjects in senior high school and to boost those pursuing STEM careers. QUT's targets are students from South-East Queensland and Regional Queensland in years 8-12 with an interest in STEM subjects. Since January, 2013 more than 4,000 have participated in this STEM outreach programme at QUT over a period of less than nine months. Academics are embracing the engagement culture through sharing their expertise with aspiring high school students, by assisting the development of workshops and by presenting their research at "Real Research" seminars for school students.

Fig. 8 Students accessing the "Physics Wall" section of "the Cube"

Integration of high school engagement activities within the SEC increases awareness of STEM careers and promotes a positive perception about secondary and tertiary studies in these disciplines. This collaborative venture focuses on a multidisciplinary approach across the QUT community to facilitate the transition from high school to University.

Other public spaces located on higher floors of the SEC include a large Atrium and a roof-top Terrace on the sixth floor. These spaces are foci for more intimate events and smaller meetings and, when not in use for events, are rapidly populated by the undergraduate cohort undertaking collaborative learning in less formal environments. These informal collaborative spaces are co-located with the Directorate of QUT's Institute for Future Environments [21] and associated analytical laboratories. This close proximity of undergraduate spaces to the research community presents a more subliminal message that allows display of the full spectrum of STEM careers to undergraduate students.

3 CONCLUSIONS

A strategic and collaborative programme directed at re-vitalising and re-developing education, research and community engagement on the Gardens Point campus has delivered high profile, successful outcomes for STEM and related disciplines. The integration of these three principal activities on the campus is a result of a strong collaboration amongst many entities and administrative bodies of the University over a period of more than five years. The success of this programme and benefits to the community are expected to have long-lasting, generational impacts not only on undergraduate attrition rates and enrolments into STEM degrees but also on general community literacy in science and engineering.

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